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LOW-FREQUENCY AMBIENT OCEAN NOISE INSTRUMENTATION.(U)

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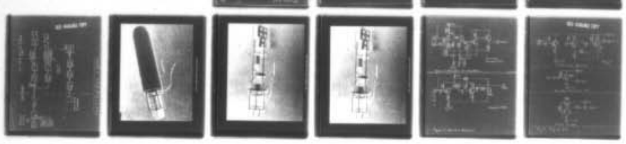

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6 LOW-FREQUENCY AMBIENT OCEAN NOISE INSTRUMENTATION.
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PREFACE

This memorandum describes instrumentation developed by Code 2322 for the measurement of low-frequency ambient ocean noise. This memorandum has been prepared because it is believed that certain features of the instrumentation and techniques may be useful to others working in allied fields at the U. S. Navy Electronics Laboratory, and only small distribution outside of the Laboratory is contemplated. This memorandum should not be construed as a report as its only function is to present for the information of others a portion of the work being done on the ambient noise program.

Some of the features believed to be of general interest are the use of transistorized electronics and the use of lightweight, easily handled deep sea equipment.

INTRODUCTION

Members of the Noise and Exploratory Studies Branch, along with others at this Laboratory and elsewhere, have in recent years exhibited considerable interest in low-frequency ambient noise in the ocean. In particular the region below 1,000 cycles per second has been of interest. The absolute levels, the spectrum, directionality, space correlation, distribution of amplitudes, and the effect of natural and man-made parameters on these quantities have been of interest. The Laboratory was not able before mid 1954, however, to engage in any measurement program designed to answer these questions.

Information on the low-frequency end of the audio frequency spectrum is of interest as both passive and active sonar equipment operating frequencies are being reduced in efforts to improve range. In past years this Laboratory and others have gained some information about noise in this region. Usually, however, it has come as a side result in other programs such as propagation, submarine noise, geophysical or Sofar studies.

Some East Coast laboratories have recently engaged in studies in the region of interest. The work at Columbia University's Hudson Laboratories and at the Bell Telephone Laboratories, Inc. has been noteworthy. Reports of the Hudson Laboratories[1] have revealed instrumentation methods which were satisfactory for their task and ours, and these

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1. Columbia University, Hudson Laboratories, Project MICHAEL, Technical Report No. 19, "Investigation of Ocean Ambient Noise at Low Frequencies; Part I, Instrumentation and Analytic Methods", by A. J. Saur and A. Berman. 15 February 1954. (Confidential).

methods have influenced our instrumentation to a considerable extent.

THE PROBLEM

As long as one is interested only in measuring ambient noise close to shore in shallow water the approach usually involves using a bottom-mounted hydrophone and a wire or wire-radio link to the monitoring station. This method is useful in measuring pressure fluctuations of as low as tidal frequency.

When one is interested in measurement far from shore in deep water a different system is needed and several requirements must be met. The monitoring station (presumably ship or aircraft) must radiate no noise which would be picked up by the hydrophone. Equally important, the hydrophone must be motionless with respect to the water as motion will introduce false signals into a low-frequency system in a number of ways. The hydrophone must, therefore, be isolated from surface and monitoring platform motion. If a connecting cable is used it must transmit no motion to the hydrophone during measurement periods. Other considerations include static pressure and temperature effects on the hydrophone and adequate signal-to-noise ratios in the quietest seas.

THE PRESENT SYSTEM

Figure 1 is a block diagram of the present instrumentation. The vertical dotted line separates the shipboard components from those in the water. The blocks shown are for the most part plug-in subassemblies.

The purpose of using plug-in units of a few standardized types is to reduce equipment "down time" at sea with a minimum of spare parts.

The system has been designed to obtain recordings of ambient ocean noise in the frequency range of 1 to 1,000 cps and at hydrophone depths up to 4,000 feet in all sea states.

Following the experience of the Hudson Laboratories it was decided that an approximately neutrally buoyant hydrophone connected by a long slack cable to a monitoring ship should be used. Since the hydrophone assembly was to be neutral in the water it would be essentially motionless provided the cable did not cause it to move due to surface motion transmitted down the cable or due to the weight of the cable. Hence a slack, neutrally buoyant cable was investigated. A two-conductor cable made neutral by the use of a considerable amount of polyethylene jacketing (specific gravity = .92) could be obtained at a cost of about $100 per thousand feet. The cable outside diameter was .32 inches and the breaking strength was 300 pounds.

While this was being considered, the success of the Hudson Laboratories in using a smaller U. S. Army Signal Corps field cable came to our attention. This is a twisted pair of wires, individually covered in polyethylene with a nylon jacket. Each conductor consists of seven strands of .011 inch wire, four strands being copper and three strands being steel. Each jacketed conductor has an overall diameter of .088 inches and the twisted pair has a breaking strength of 200 pounds. The cable cost is about $15 per thousand-foot pair and is available under U. S. Navy Stock Number GX-15-C-39125. The cable in

sea water weighs only about four pounds per 1,000 feet. Compared with the neutral cable discussed above it is much cheaper, more flexible, occupies less volume, is easier to splice and does not require a level-winding winch. On deck it is lighter; 10,000 feet can easily be hand-carried onboard on a portable reel winch. Hence a ship's winch is not needed and flexibility in the choice of ships is achieved. The small weight of the cable in water is believed to be no serious disadvantage and, aside from a certain amount of care required to prevent damaging, the wire is quite satisfactory. Reeling in speed is limited by the strength of the wire but at present the wire is reeled in at 300 feet per minute by a 1/2 horsepower motor with a frictional drag due to several thousand feet of wire and the hydrophone assembly.

To the left of Figure 1 is the hydrophone assembly. The hydrophone itself is a barium titanate cylinder six inches in diameter and four and one-half inches long, designed and constructed by the NEL Transducer Branch. It is designed to cover the frequency range of 1 to 1,000 cps with a usable response at 7 KC for a reason to be discussed later. The designed open circuit voltage sensitivity is -80 db re 1 volt for a sound field of one microbar and the design capacity is about .024 microfarad. Complete calibration of the unit is pending, but preliminary calibrations indicate a sensitivity of -75 db re 1 volt // microbar and capacity .006 microfarad.

To compensate for the weight of a certain amount of the cable the hydrophone assembly is made a few pounds light of neutral buoyancy

so that the wire from ship to hydrophone assumes a catenary shape. Were it not for differential drift between hydrophone and ship, the hydrophone assembly would assume a depth such that the weight of its portion of the slack-wire catenary would balance its positive buoyancy and the system would become motionless, with depth controlled by the amount of cable out. In practice, however, the two tend to drift apart and more cable must be paid out to keep it slack. To date only about 3,000 feet of cable have been used but plans call for the use of 10,000 feet or more. This should give satisfactory acoustic samples of thirty minutes' to two hours' duration depending upon the differential drift rate.

Because the hydrophone has a negative buoyancy in water and because associated preamplifier and batteries likewise add some weight, the housing in which the electronics are installed was made to have enough buoyancy to make the whole assembly a few pounds light of neutral. A cylindrical aluminum housing was designed by the Marine Equipment Section of the NEL Mechanical Engineering Division. The housing is approximately thirty-two inches long by nine inches outside diameter, and is made of one-fourth or five-sixteenths inch tubing. One end is welded shut and the hydrophone and all stuffing glands are mounted to the other end which is removable along with all of the interior electronics. Figure 2 is a photograph of the assembled unit while Figure 3 shows it with the pressure case removed. The unit is self-powered by two -45 volt BA-63 batteries in series, and four six-volt BA-210 batteries in parallel. Battery life is about twenty hours.

To assist the hydrophone assembly in sinking rapidly to the desired sampling depth an extra weight of about ten pounds is attached. This weight is automatically released at a pre-set depth by a pressure actuated release mechanism.

The electronics consist of several plug-in units. The preamplifier is a unit with 28 db of voltage gain and an output impedance of 250 ohms. The equivalent input noise spectrum levels when used with the hydrophone are -143 db at 40 cps and -158 db at 10 KC; both values are in reference to a one volt input level.

The circuit is shown in Figure 4. It is a feedback stabilized unit of four stages: triode amplifier, cathode follower, grounded emitter transistor and grounded collector output. A 10 ohm resistor is in series with the hydrophone lead to permit the insertion of a calibration signal while the unit is on deck.

Another plug-in unit is a transistor amplifier which works in conjunction with a Vibratron pressure gauge to give oscillations, the frequency of which indicates hydrophone depth. Figure 5 indicates the circuitry involved. The Vibratron gauge, made by the Byron-Jackson Company of Los Angeles, consists of a taut wire in a magnetic field. The wire acts as a parallel resonant circuit when a voltage is applied to its ends. The resonant frequency is the mechanical resonant frequency of the wire, in this case, around 3 KC. Pressure changes in the measured medium change the tension on the wire and hence the resonant frequency. The unit together with the associated amplifier forms an oscillator, the output of which is introduced into the

hydrophone preamplifier and hence up the two-conductor cable to the ship. The unit measures 0 to 2,000 psi pressure giving an output which varies from 3,210 to 2,875 cps; this falls in one of the RDB recommended telemetering channels.

Spaces for other plug-in units are available and likewise other telemetering channels are available for supporting data. A temperature-indicating oscillator is under development and an acceleration-indicating oscillator is being considered. Since acoustic data up to 1,000 cps are of primary interest, much spectrum remains above this for other data.

All cables leave the interior through double watertight seals. A three-conductor plug adjacent to the hydrophone allows electrical calibrations to be made when the unit is on deck. The unit is turned on and off through the use of a shorting plug.

Since transistorizing was helpful within the submerging hydrophone assembly its use was contemplated for the surface electronics. Points in favor of transistors were freedom from 60 cps hum, decrease in size and weight, perhaps an increase in reliability and freedom from AC power requirements. This last is of some importance since a ship's normal power supply is turned off during measurements to cut down radiated ship noise. At present a vibration-isolated AC generator is required for recording and monitoring equipment and the eventual abandonment of even this is contemplated.

For the surface instrumentation the use of several standardized plug-in units is desirable. Perhaps most important is a feedback-

stabilized voltage amplifier of 40 db gain and a frequency response flat from 1 cps to above 10 KC. Input impedance is 60,000 ohms and output impedance is 3,500 ohms. Since the unit normally works from a six-volt battery, the output voltage is kept below the one-volt RMS level to minimize distortion. Another plug-in unit is a grounded collector unit which gives essentially unity voltage gain but an impedance reduction by a factor of about ten. Still another plug-in unit is a 7.2 K.C. oscillator. This unit uses a point-contact transistor satisfactorily although the unit may be redesigned for the more dependable junction transistor. Figure 6 indicates circuitry of these plug-in units. These units do not necessarily indicate optimum design but they do work satisfactorily.

Another look at Figure 1 indicates that the signal transmitted up the cable contains both acoustic information and auxiliary data on hydrophone depth, etc. Onboard ship the signal is conveyed into separate channels. All of the frequencies present are fed to a variable 50 db attenuator, thence through plug-in amplifiers to monitoring and recording channels. At present the recording is done on two magnetic tape units. The primary recorder is a factory-modified Ampex, model S-3462, which has a recording frequency response good from 10 cps to 7,500 cps when recorded at 3-3/4 ips and played back at 7-1/2 ips. The other recorder is a direct recording Stancil-Hoffman, model R4-LS, which has a record speed of .2 ips and when played back at 7-1/2 ips will reproduce recorded frequencies from .5 to 200 cps.

Still referring to Figure 1 it is noted that the high frequency information is fed into amplifiers and thence to telemetering band-pass filters. The coupling condensers shown are of such values that low frequencies are much attenuated. An electronic frequency meter applied to the filter outputs will indicate hydrophone depth or other telemetering quantities. The bottom band-pass filter feeds the stylus of a chemical range recorder through a 40 db amplifier. The keying circuit of this recorder keys the 7.2 KC oscillator whose output is amplified and drives a small barium titanate transducer. These pings are picked up by the remote acoustic hydrophone and sent up the cable to the range recorder, thus giving slant range from ship to hydrophone. This information is desirable in the proper control of the hydrophone and the interpretation of the data.

The instrumentation described here is only part of the instrumentation actually used at sea. Additional supporting instrumentation includes a recording anemometer and a continuously running recorder indicating noise levels as measured on an AN/PQM-1A noise measuring set.

RESULTS

The system has been taken to sea on a number of one-day trips into areas which have not been free from effects of nearby shipping. The ambient noise levels measured in the region of 100 to 1,000 cps compare with results obtained earlier with other equipment in waters

exhibiting similar traffic noise. No measurements of true sea noise have yet been made.

FUTURE PLANS

Cruises of approximately two weeks' duration, each, are planned about once a quarter for the next eighteen months. The first cruise is scheduled for the M.V. STRANGER starting 20 September 1955.

Equipment changes will be made as desirable and as time permits. Efforts are continually being made to decrease the bulk and weight of the equipment and perhaps to make it all battery-powered. The present transistor circuitry is still experimental but promising. If small battery-powered equipment is attained, it will permit operation ease not now possessed. Operation from small boats or perhaps hovering helicopters or a portable set-up on an ice floe may then be feasible.

It is believed that some of the instrumentation used here may find use in other projects. In particular the lightweight cable and handcarried winch along with the neutral instrument canister permit operation on any ship. The old problem of cable not strong enough to support its own weight is avoided and equipment even light enough for a scientist to handle may sometimes be achieved.

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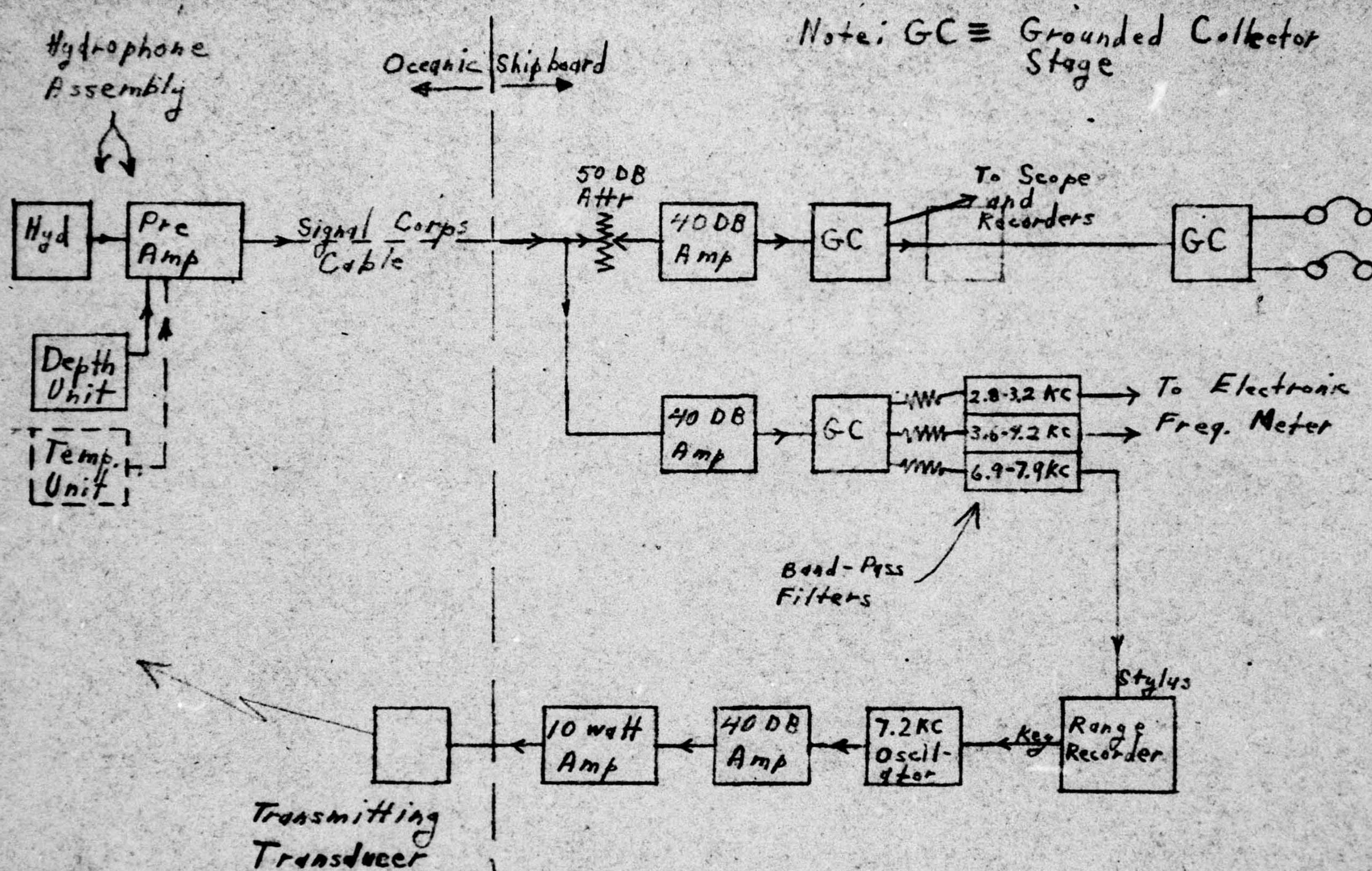


Figure 1 - Block Diagram of System

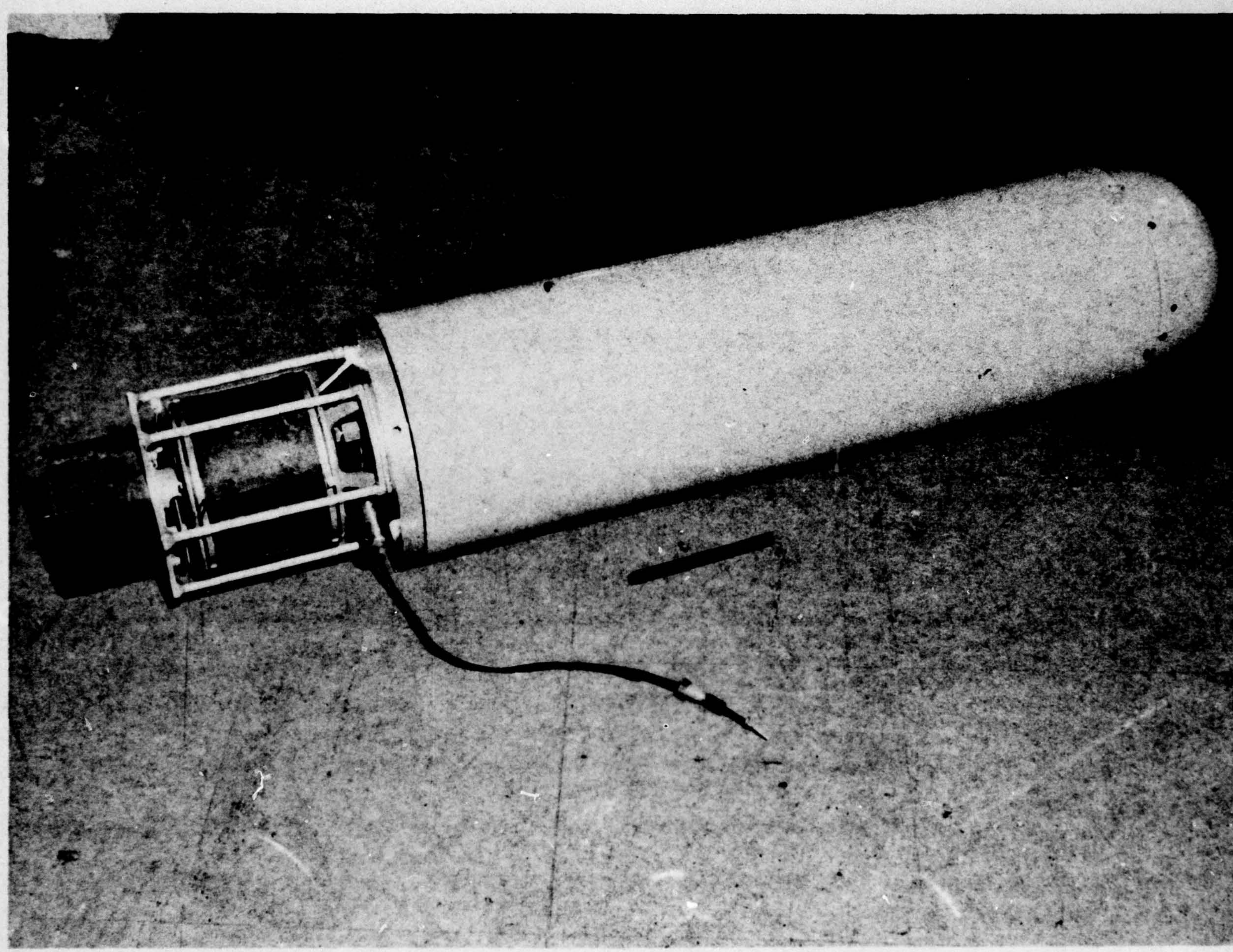


Figure 2. Hydrophone assembly with sinking weight attached.

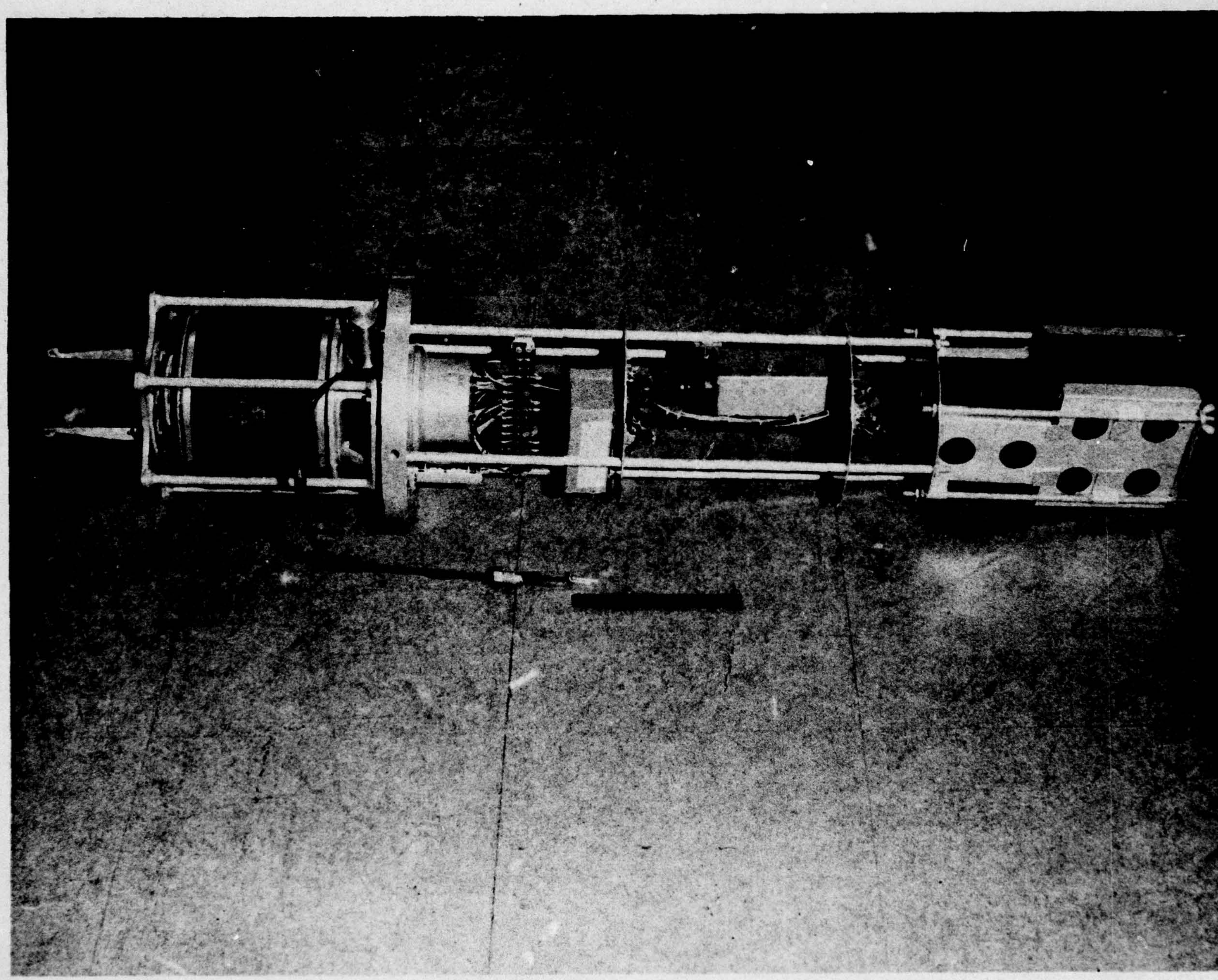


Figure 3. Hydrophone assembly interior (sinking weight removed).

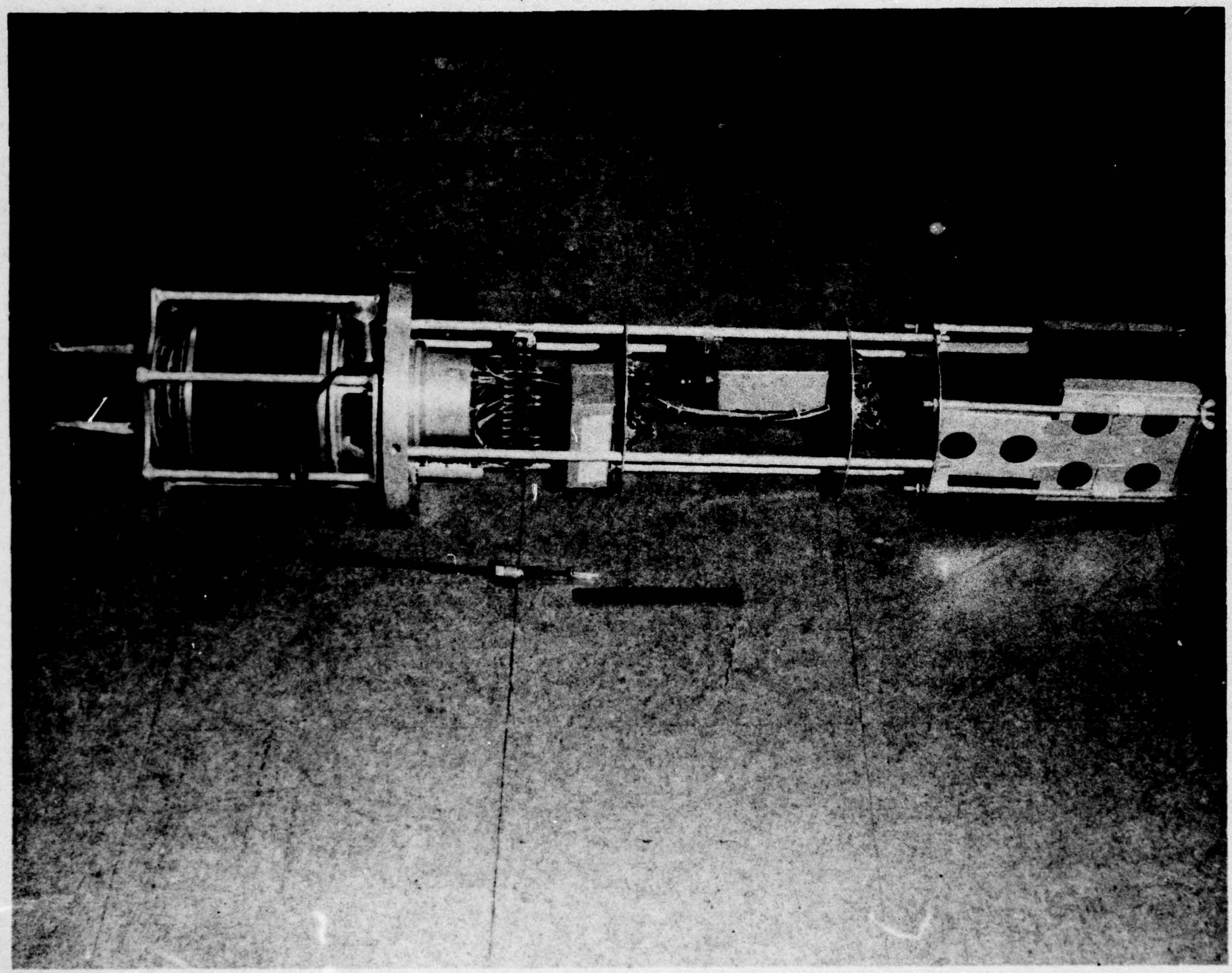


Figure 3. Hydrophone assembly interior (sinking weight removed).

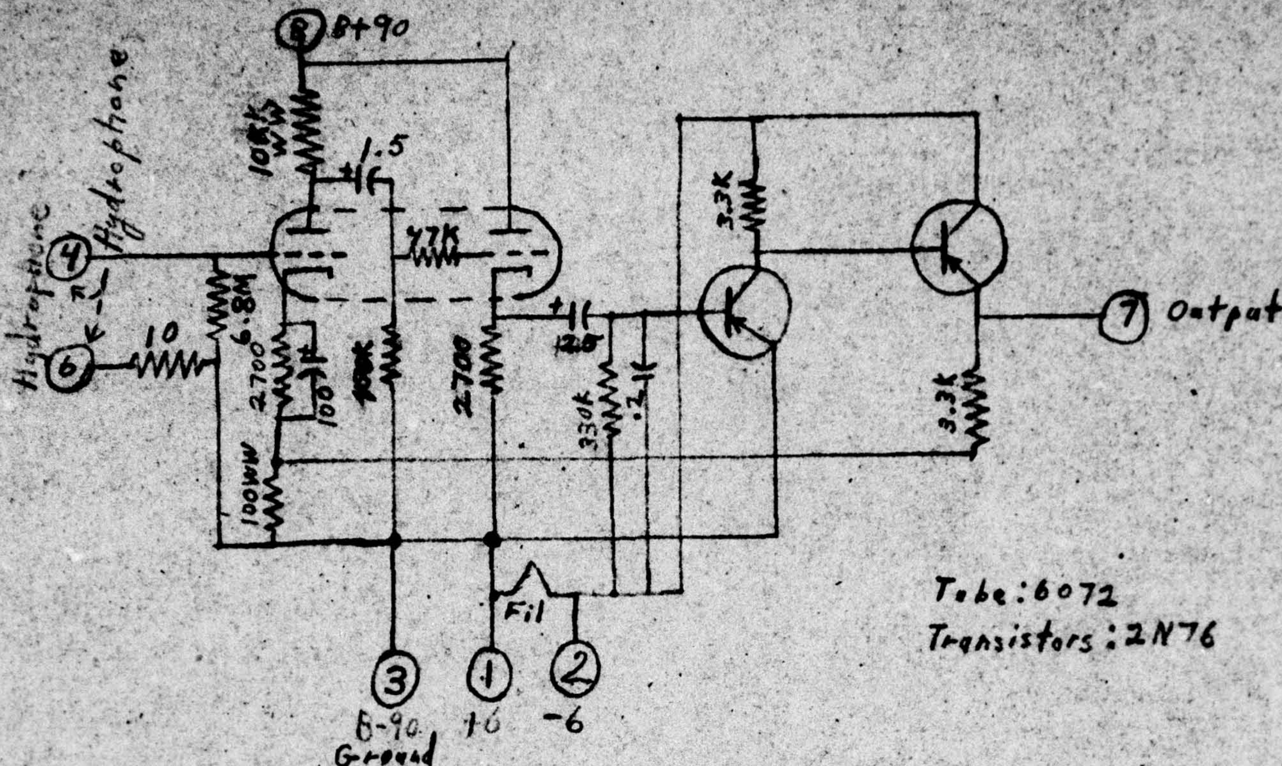


Figure 4: Hydrophone Pre-Amplifier

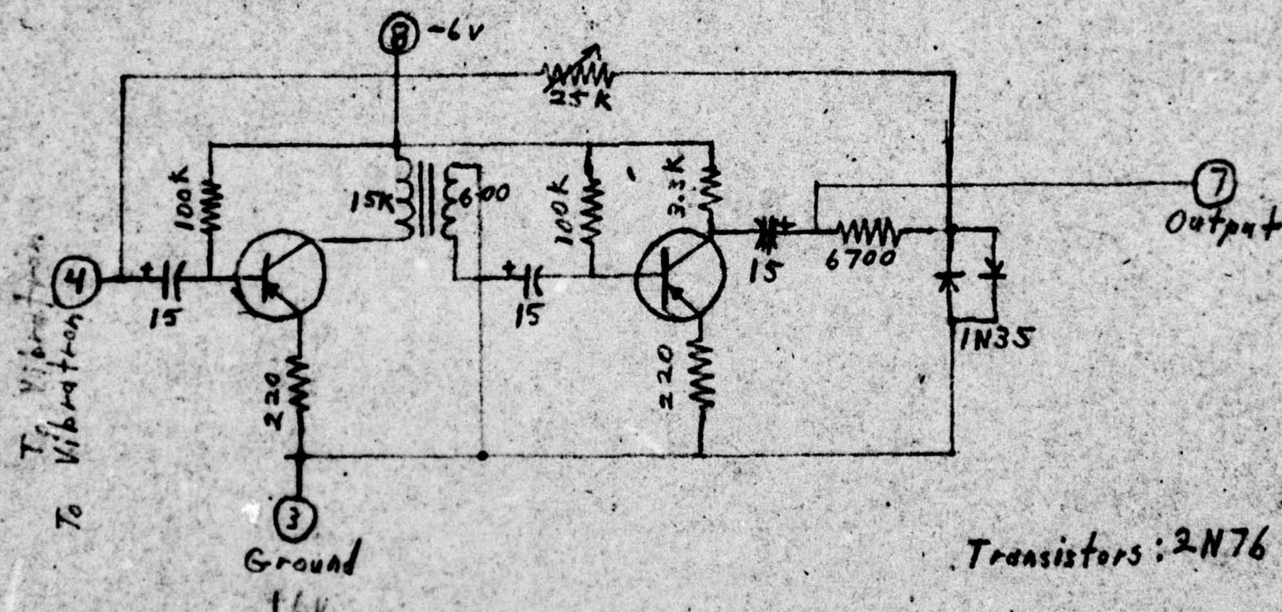
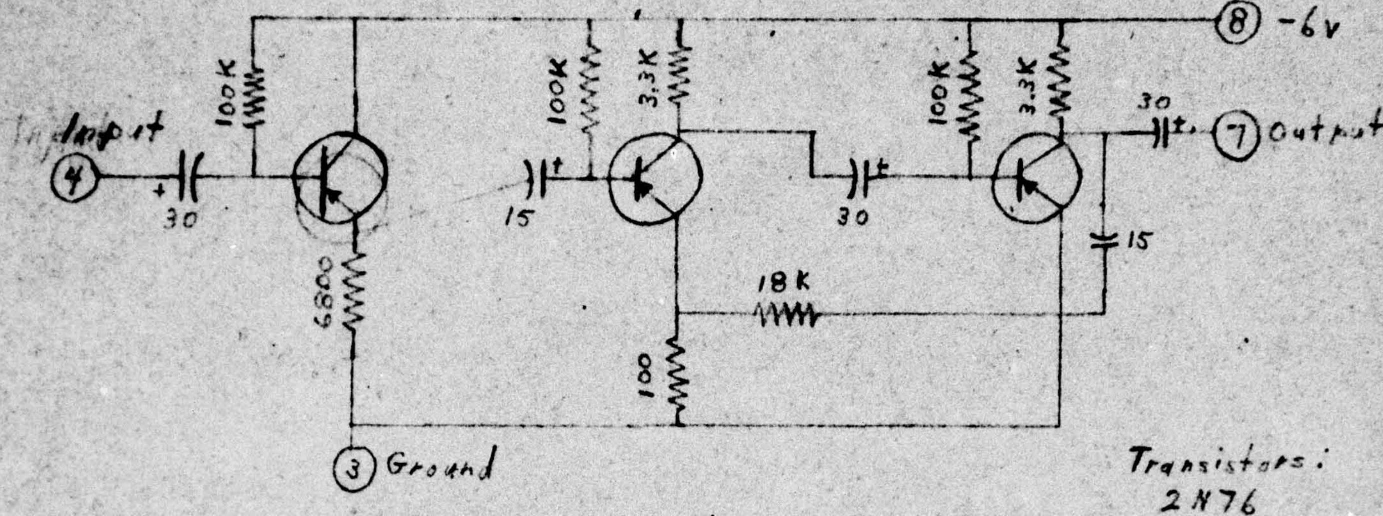
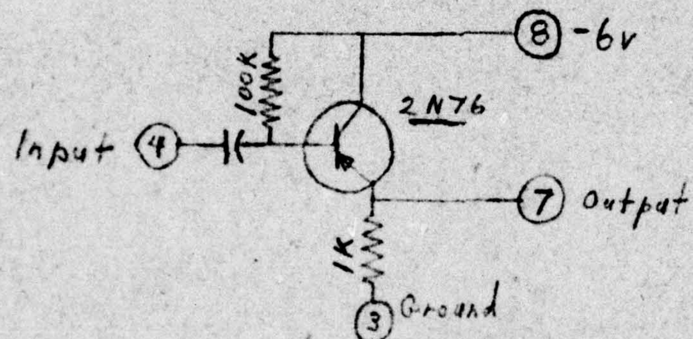


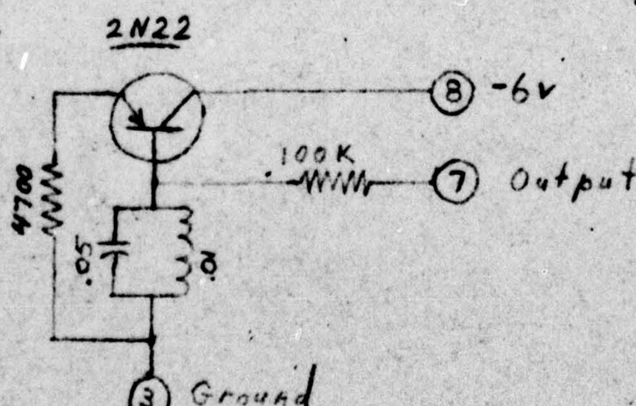
Figure 5: Vibratron Amplifier



40 DB Voltage Amplifier



Grounded Collector Unit



7.2 KC Oscillator

Fig 6: Plug-In Units